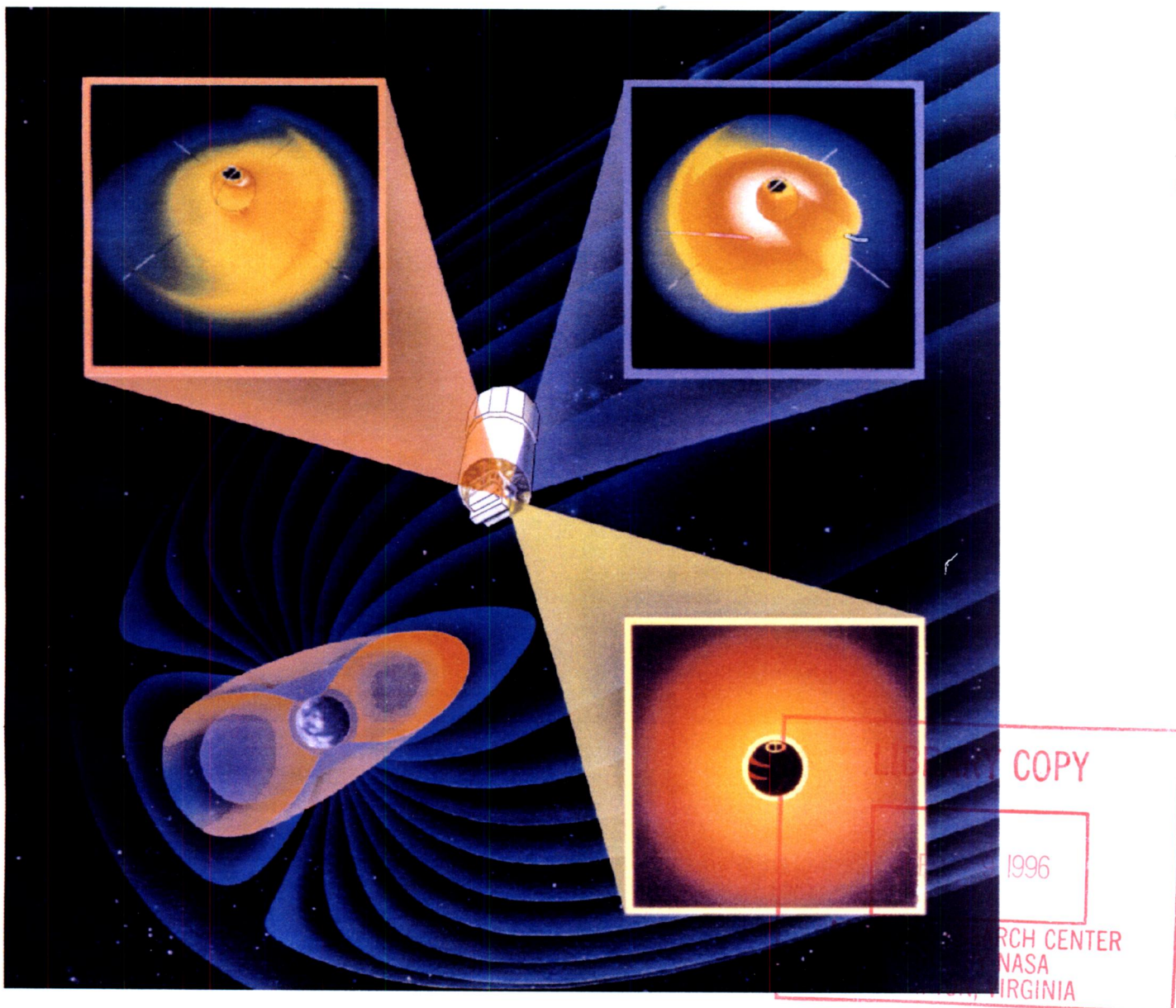


# Magnetosphere Imager Science Definition Team—Executive Summary

*T.P. Armstrong, D.L. Gallagher, and C.L. Johnson*





National Aeronautics and  
Space Administration  
**George C. Marshall Space Flight Center**  
Marshall Space Flight Center, AL 35812



*Inserted  
5-8-96  
mfp*

Reply to Attn of:

**ES83(96-15)**

**March 26, 1996**

**TO: Recipient of MI - Executive Summary**

**FROM: ES83/Dennis Gallagher**

**SUBJECT: MI Executive Summary Errata**

An error has been discovered in the document "Magnetosphere Imager Science Definition Team--Executive Summary", NASA Reference Publication-1379. As a result, the enclosed Errata has been produced on a self adhesive label for attachment to the bottom half of page ix.

Please accept our apology for any inconvenience this may have caused and attach the Errata as indicated to your copy of the document.

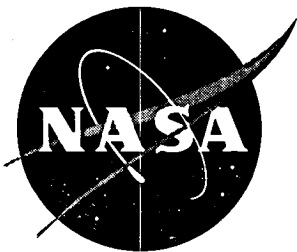
Sincerely,

A handwritten signature in cursive script that reads "Dennis Gallagher".

Dennis Gallagher  
MI Study Scientist  
Space Plasma Physics Branch

Enclosure





# Magnetosphere Imager Science Definition Team—Executive Summary

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*University of Kansas, Lawrence, Kansas*

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## **PREFACE**

This Executive Summary report was originally prepared in 1991 to support what was then called the Inner Magnetosphere Imager (IMI) Science Definition Team. Since that time, the IMI science objectives and mission concept have been significantly rescoped. The new mission concept, the Magnetosphere Imager, is simply the evolved IMI described herein. The companion volume to this report, the Magnetosphere Imager Science Definition Team Interim Report, is being simultaneously printed as a NASA Reference Publication. The two missions, hence also the information contained within the two reports, differ not in overall science justification, but in suggested implementation: strawman instruments, spacecraft, and suggested launch vehicles have changed considerably since this report was originally drafted.





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## **Membership of the Magnetosphere Imager Science Definition Team**

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### **ERRATA**

#### **NASA REFERENCE PUBLICATION-1379**

#### **MAGNETOSPHERE IMAGER SCIENCE DEFINITION TEAM --EXECUTIVE SUMMARY**

By T. P. Armstrong, D. L. Gallagher, and C. L. Johnson

September 1995

Due to an oversight, one of the MI Science Definition Team members was omitted from the list. Please note that the list should include:

Robert R. Meier

Naval Research Laboratory

Also note that James L. Green, from the above list, and the Radio Plasma Sounder Team were included in the MI mission definition effort following the completion of this Executive Summary. Hence, their contribution to defining the MI mission can only be found in the "Magnetosphere Imager Science Definition Team Interim Report," NASA Reference Publication 1378.

## **Membership of the Radio Plasma Sounder Team**

The Space Physics Division convened an ad hoc panel to evaluate the scientific feasibility and potential return from a radio plasma sounding (RPS) investigation of the magnetosphere. This possibility arose via suggestions that RPS might provide a valuable enhancement to MI science.

James L. Green (Chairman)

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Shing Fung

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Dr. Connie Carrington	Attitude Control and Determination
Greg Hajos	Configuration Layout
George Kearns	Propulsion
Larry Kos	Orbit Analysis
Lou Maus	Electrical Power System
Andy Price	Cost Analysis
Terri Schmitt	Launch Vehicle Performance
Susan Spencer	Structural Analysis





## REFERENCE PUBLICATION

### MAGNETOSPHERE IMAGER SCIENCE DEFINITION TEAM EXECUTIVE SUMMARY

#### I. MISSION SUMMARY

##### A. Scientific Objectives

(1) To understand the global shape of the inner magnetosphere using simultaneously obtained images of the Earth's magnetosphere and its components: the ring current, the inner plasma sheet, the plasmasphere, the aurora, and the geocorona.

(2) To learn how magnetospheric current systems, field configurations, and conductivities derived from images respond on a global scale to internal and external influences.

(3) To visualize and identify the connections of various magnetospheric components to each other, especially as these connections act to change the components during substorms and solar wind variations.

(4) To relate global images of the magnetosphere to local observations in order to (a) learn how local processes combine to form the whole, (b) provide a global framework within which to place local observations, and (c) provide a "ground-truth" for the global observations.

##### B. Measurement Objectives

To obtain the first simultaneous images of component regions of the inner magnetosphere:

(1) The ring current and inner plasma sheet using energetic neutral atoms (ENA's)

(2) The plasmasphere using extreme ultraviolet (EUV)

(3) The electron and proton auroras using far ultraviolet (FUV) and x rays

(4) The geocorona using FUV.

##### C. Spacecraft and Orbit

(1) Guideline orbit: 400-km perigee by 5  $R_E$  apogee altitude orbit, 90° inclination, Delta-class launch

(2) 1,368-kg spacecraft launched weight, including instruments; nominal performance characteristics, orbit-normal spin, and with a single-axis pointed despun platform

(3) Preliminary cost estimates range from \$177 M to \$255 M (launch not included).

## II. SCIENTIFIC BACKGROUND

The study of the Earth's magnetosphere with spacecraft-borne instruments which measure magnetic fields, plasmas, and electric fields has yielded many fundamental discoveries. A few of these are:

- Geomagnetically trapped radiation
- Collisionless magnetohydrodynamic shocks
- The geomagnetic tail, plasma sheet, and neutral sheet
- Auroral kilometric radiation.

In many instances, magnetospheric observations have both exhibited the phenomena expected from fundamental new theories (e.g., geomagnetically trapped charged particles) and inspired the development of theories (e.g., collisionless MHD shocks). Magnetospheric physics has become one of the mature space sciences and has given birth to the general research discipline of space plasma physics; a discipline recognized by the U.S. National Academy of Sciences as "... intrinsically an important branch of science."<sup>1</sup> The many successes in this field have been based almost completely on spacecraft observations of local phenomena, combined with vigorous application of theory. However, the ideas that currently guide magnetospheric physics in forming a description of the entire system and its macroscale regions are based on a very limited set of observations and, as a result, are qualitative and schematic in concept. These observations include multispacecraft observations, both planned and fortuitous, and pioneering spacecraft studies that use global imaging. The most productive studies have been those with the auroral imaging instrumentation carried by Dynamics Explorer 1 (DE-1). Figure 1 shows a global view of the aurora australis, which displays a hitherto undiscovered phenomenon, the "theta aurora" (an appellation based on its shape). This vividly illustrates the power of global imaging as a tool for discovery.

Recently, the scientific and technological bases for imaging other macroscale features of the magnetosphere have been developed. The Earth's neutral hydrogen geocorona glows in resonantly scattered solar ultraviolet (UV) light as shown in figure 2. The auroral oval and equatorial airglow are obvious near-Earth features. The geocorona, which consists of neutral hydrogen atoms, is seen as the diffuse luminosity that extends far from the Earth. As magnetospheric-charged particles move through the geocorona, they occasionally capture an electron from a hydrogen atom. The result of this process is that an ENA is formed. The ENA is freed from electrical forces and flies off in a straight line. As shown in figure 3, the ENA can be detected by a sensor located remotely from the site of ENA generation. Since the ENA can be assigned precise arrival directions and speeds, images are thereby obtained. This method yields quantitative, global information on the entire distribution of magnetospheric plasma and energetic particles.

Up to the present time, this method has been applied only to the observations of an instrument aboard the International Sun Earth Explorer 1 (ISEE-1) spacecraft. This instrument was designed to survey charged particles but was incidentally sensitive to ENA, thus its images were very coarse and its sensitivity was low. Nevertheless, as shown in figure 4, it was possible to build a coarse ENA magnetospheric image from ISEE-1 measurements. Analysis of this image, in terms of plasma distributions and electrical currents, exhibited global patterns that promise a meaningful synthesis of global and local observations.

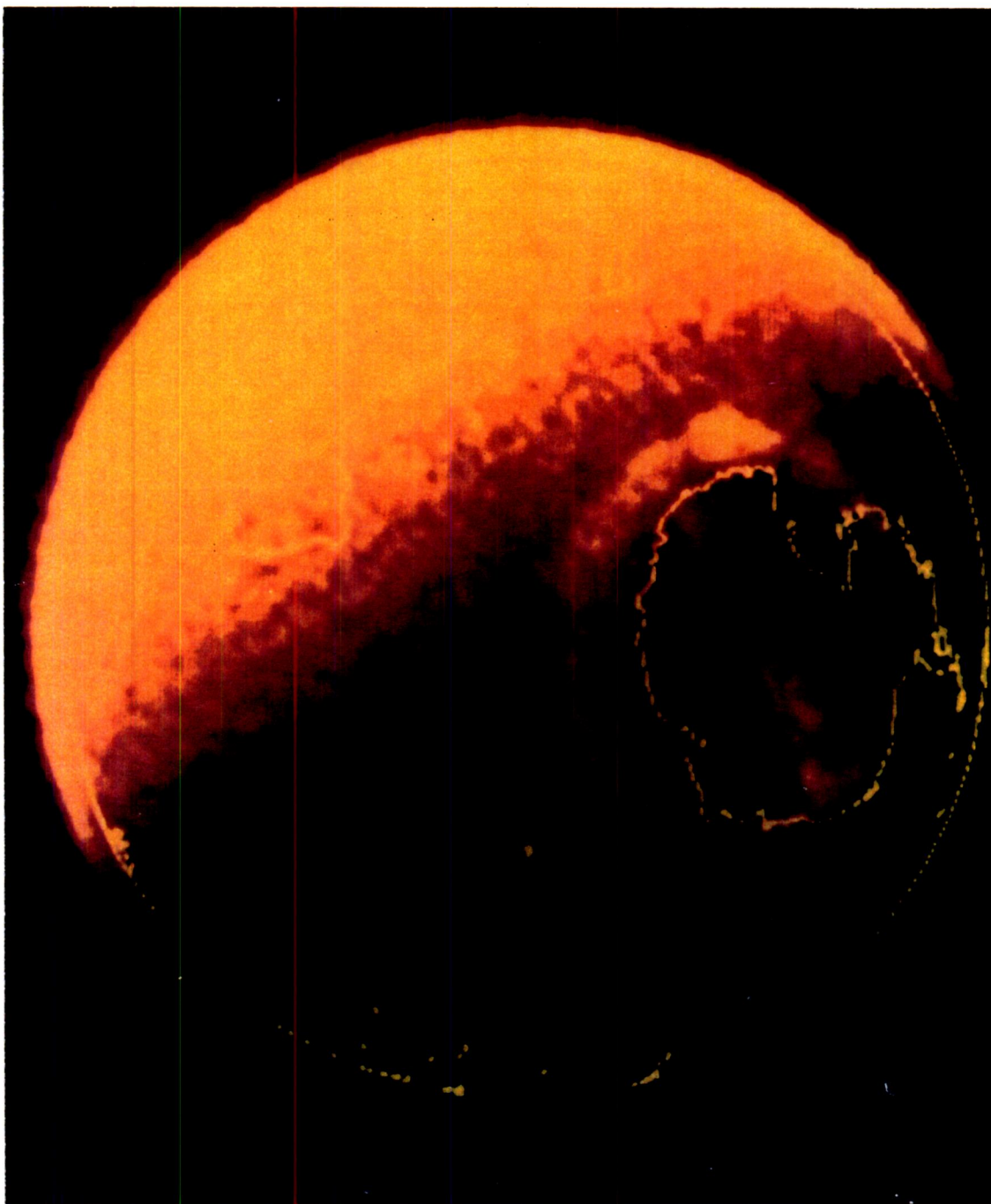


Figure 1. DE-1 UV image of the “theta aurora” over Antarctica on May 11, 1983.



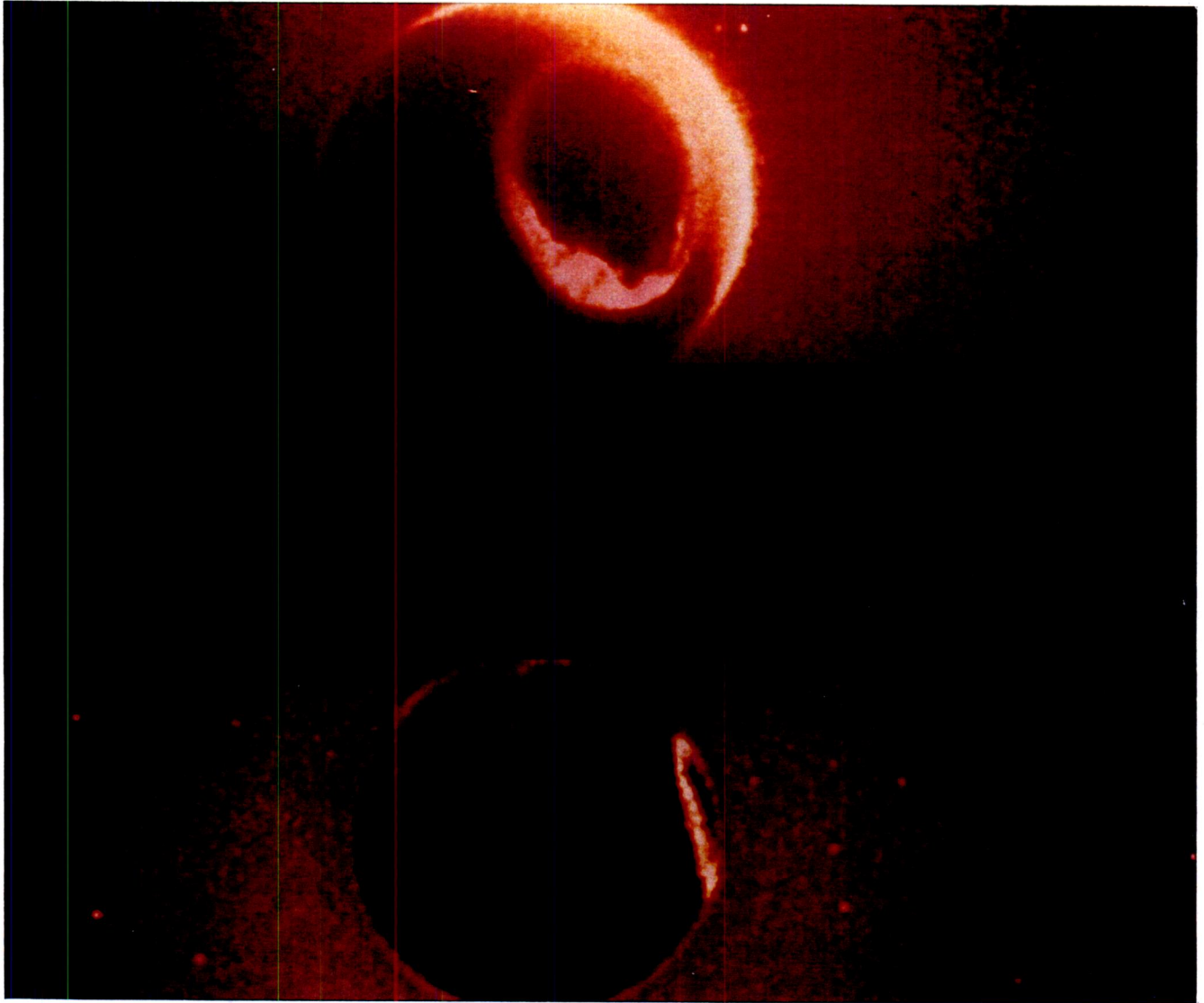


Figure 2. DE-1 polar and equatorial views of the Earth, the aurora, the equatorial airglow bands, and the geocorona.



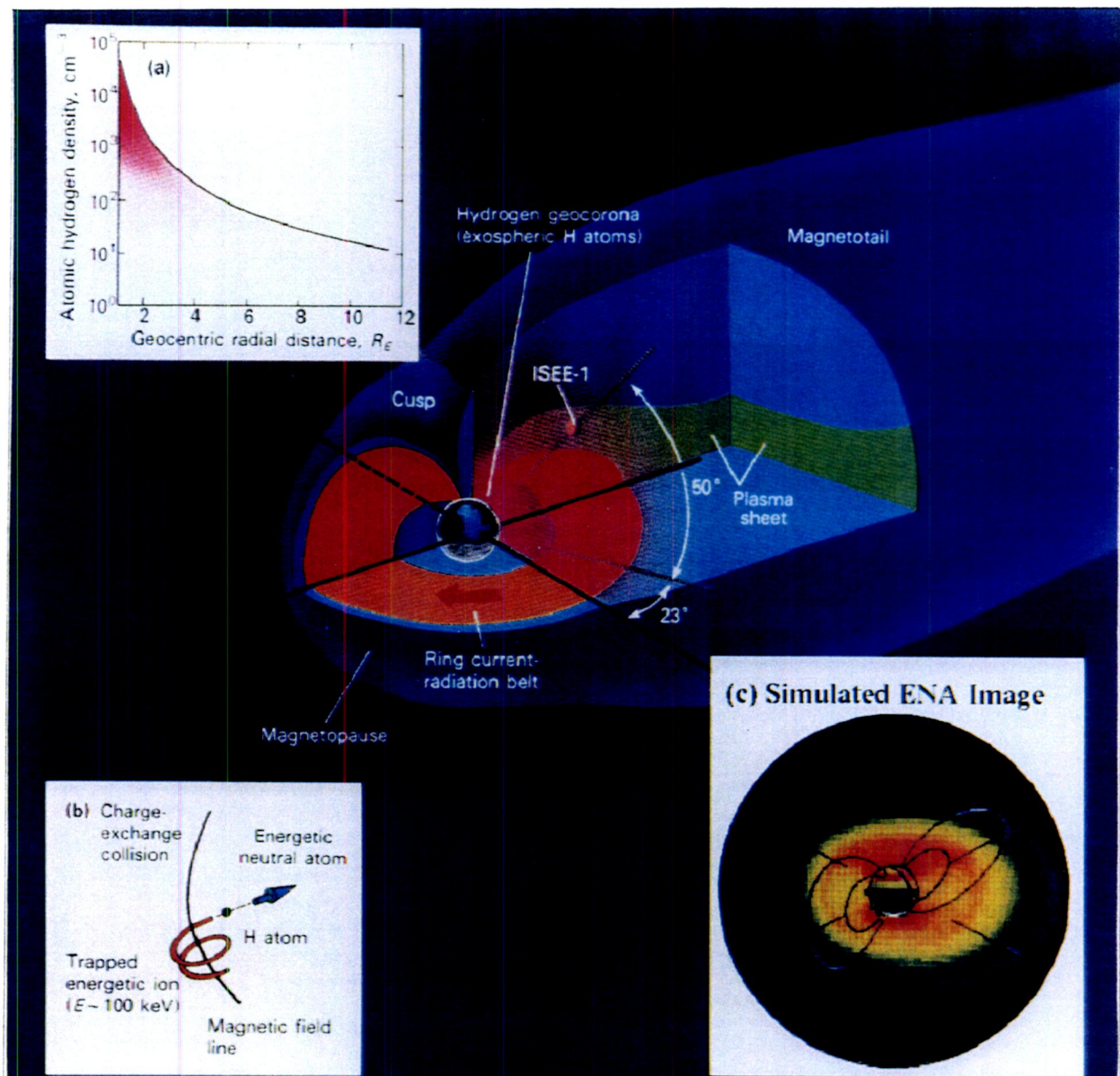


Figure 3. Diagrammatic representation of the elements of the charge exchange process that generates ENA's.





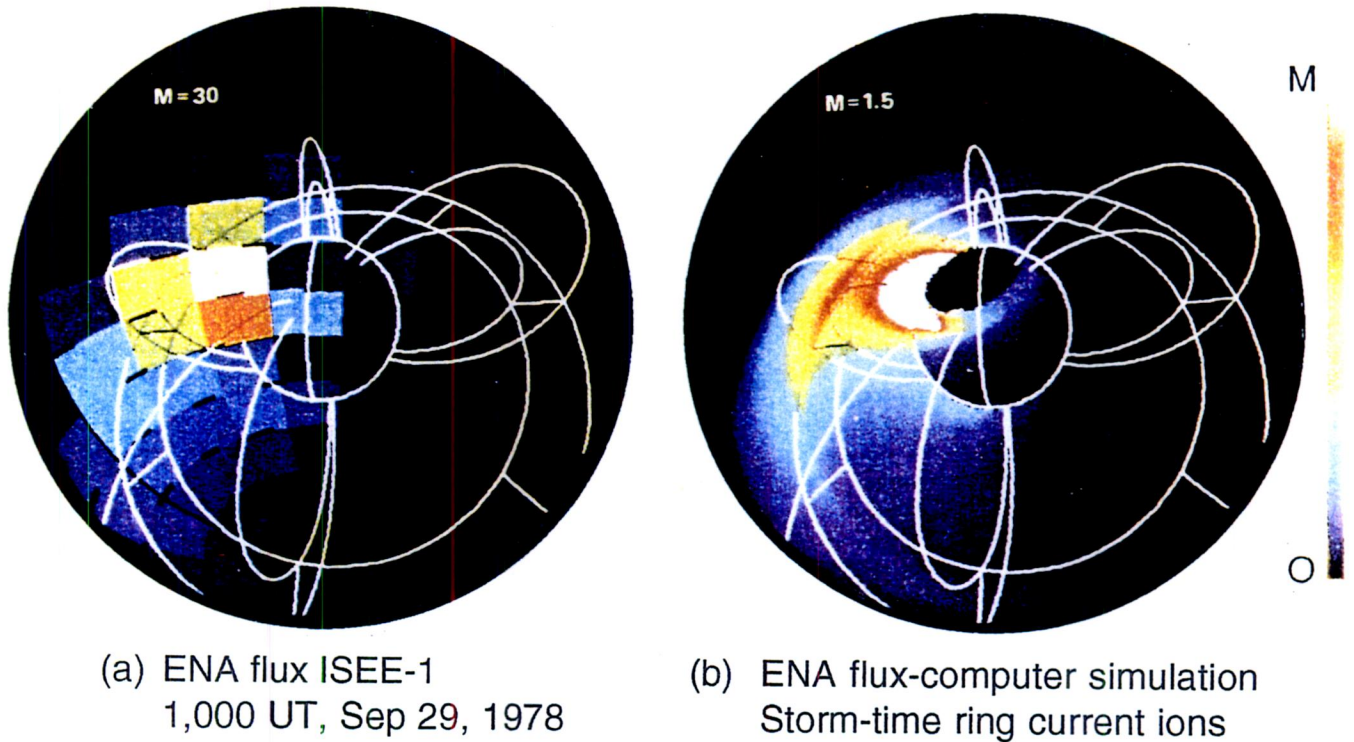
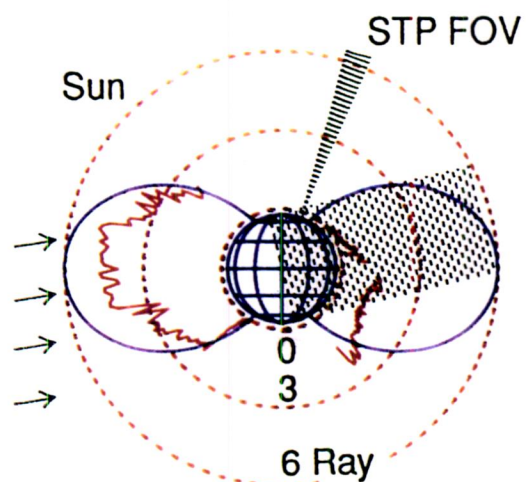


Figure 4. ENA images of the magnetosphere: (a) ISEE-1 observations and (b) simulated with  $1^\circ$  resolution.

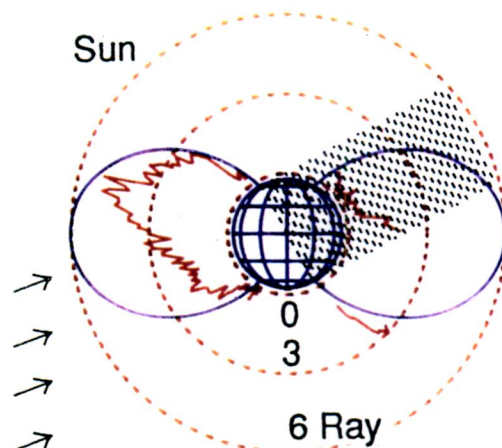
The cold plasma constituent of the magnetosphere, the plasmasphere, can also be imaged in resonantly scattered solar UV at  $304 \text{ \AA}$ . Figure 5 illustrates diurnal and seasonal variations of the plasmasphere, measured from low altitudes. The instrument in this case was not an imager, but rather measured the integrated luminosity along an upward line of sight. A uniformly filled plasmasphere would occupy the region interior to the blue curves. The observations are plotted in red. It can be seen that the plasmasphere has important daily, seasonal, and other temporal variations. Global electric fields are a major factor in determining the shape and appearance of the plasmasphere. Figure 6 shows how the plasmasphere is thought to respond to various hypothesized electric field patterns and time variations. Expected polar plasmaspheric views can be compared directly with the observations that the inner magnetosphere imager (IMI) would obtain, and the global convection electric field, in the inner magnetosphere, can be inferred by this process.

Figures 1 to 6 illustrate the possibilities for global imaging. However, IMI will have more sensitive, higher resolution instruments (typically gaining factors of 10 to 100) and will obtain global images of the four magnetospheric components at the same time. It is believed that this is the most effective way to study the global dynamics of the magnetosphere and to make progress in explaining how it works.

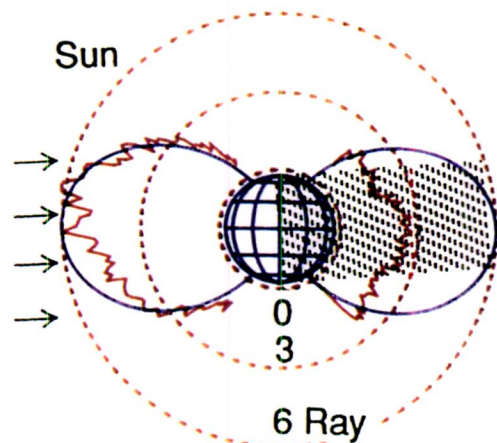




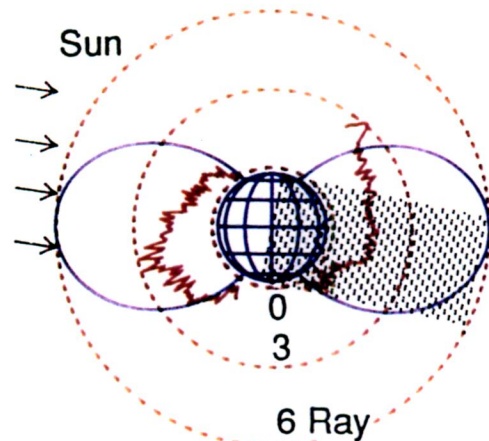
11/16/72 Orbit 650;  
 $F_{10.7}=92$   $A_p=31$



1/25/73 Orbit 1651;  
 $F_{10.7}=116$   $A_p=8$



2/17/73 Orbit 1992;  
 $F_{10.7}=96$   $A_p=16$



6/13/73 Orbit 3517;  
 $F_{10.7}=103$   $A_p=34$

Figure 5. Observations of  $\text{He}^+$  304 Å plasmaspherically scattered solar UV.





## ACTIVE PLASMASPHERE

He<sup>+</sup> 304Å image from:  
R = 5 R<sub>E</sub>  
MLAT = 60 deg  
MLT = 2100 h

E-field convection signatures:

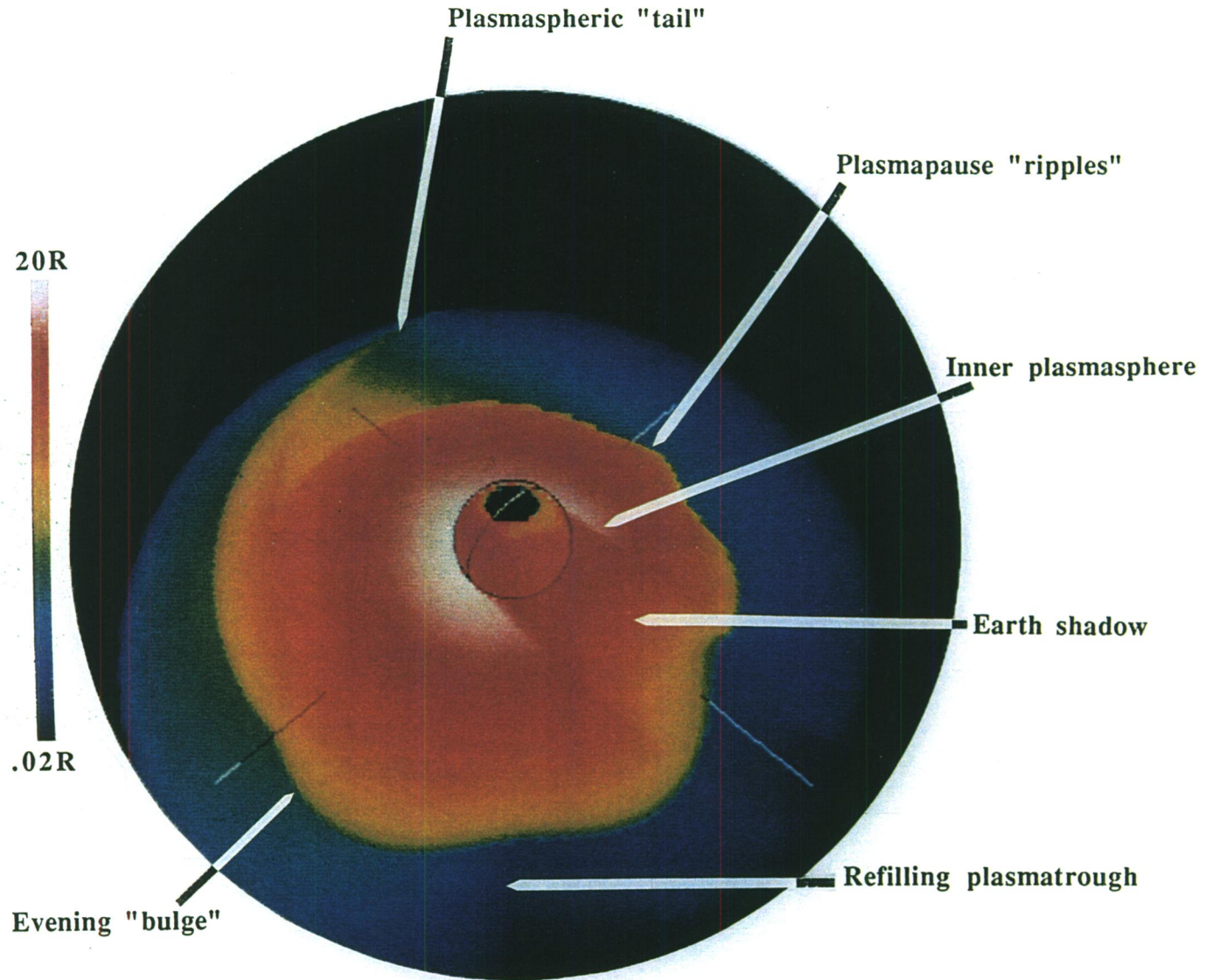


Figure 6. Modeled response of plasmasphere to hypothesized, time-varying electric fields.



### III. MISSION PROFILE

#### A. Orbit

	<u>Baseline Orbit</u>	<u>Optional Orbit (Second Year)</u>
Perigee Altitude	400 km	1.5 $R_E$
Apogee Altitude	5 $R_E$	9 $R_E$
Inclination (initial apogee over North Pole)	90°	90°

#### B. Vehicle

(Delta II 7925 with standard 2.9-m fairing for launch vehicle)

<u>Weight (kg)</u>		<u>Power (Watts)</u>	
Instruments	181.5	Instruments	175
Subsystems	670.9	Subsystems	135
Contingency	255.7	(Active solar array 123.5 ft <sup>2</sup> )	
Propellant	260.1		
	<hr/> 1,368.2		

Spacecraft Data Rate: 56.2 kbps

Recorder Storage: 1.29×10<sup>9</sup> b

#### C. Strawman Instruments

<u>Description</u>	<u>Spectral Range</u>	<u>Angular Resolution</u>
Hot Plasma Imager (ENA)	1 to 1,000 KeV	~3°
Plasmasphere Imagers (He <sup>+</sup> and O <sup>+</sup> )	304 Å and 834 Å	0.5°
Geocoronal Imager (Lyman-α)	1,216 Å	1°
Auroral Imager (FUV)	1,304 Å, 1,356 Å, LBH	0.03°
Proton Auroral Imager (Lyman-α)	1,216 Å ± 40 Å	0.06°
Electron Precipitation Imager (x ray)	~0.3 to 10 KeV	0.02°

### IV. SCIENTIFIC MERIT

#### A. Scientific Objectives and Significance

##### 1. What are the key scientific issues being addressed by the mission or initiative?

IMI will simultaneously obtain the first global images of the Earth's magnetosphere and its component regions. The synthesis of three decades of in situ magnetospheric measurements have revealed a tantalizing but crude picture of the global magnetosphere; tantalizing because of the brief glimpses provided of the magnetospheric configuration; and crude because these glimpses are based on measurements widely separated in space and time. To progress scientifically in understanding the global

magnetosphere and how local processes combine to form the whole, it is necessary and technically feasible to render visible the previously invisible magnetosphere. This will be done with instruments on an orbiting platform which measures UV emissions and ENA's. The questions to be addressed by IMI are basic:

- (a) What does the global magnetosphere look like in quiet and disturbed conditions?
- (b) How do the principal magnetospheric regions globally change in response to internal and external influences?
- (c) How are the principal magnetospheric regions interconnected?
- (d) What are the remote global signatures of the important astrophysical plasma processes?

2. How significant are these issues in the context of science?

In 1958, the discovery of geomagnetically trapped radiation by instruments aboard Explorer I destroyed the then-prevailing idea that the regions in space above the Earth's neutral atmosphere were relatively barren of dynamic phenomena. The exploration of this region, the magnetosphere, has added a rich array of new scientific concepts to our description of nature and, as mentioned earlier, has given rise to the general research discipline of space plasma physics. Identification of the sources and the subsequent energization of magnetospherically contained radiation has been an important theme of space science. Observing and explaining these plasma processes in the Earth's magnetosphere has given a firm basis for extending the application of fundamental plasma ideas throughout the universe.

In the solar system, local observations have shown that Mercury, Earth, Jupiter, Saturn, Uranus, and Neptune have magnetospheres and associated charged particle populations. Venus, Mars, and comets, although devoid of magnetically trapped radiation, do display other characteristic hot plasma phenomena that arise from their interactions with the solar wind. Emissions of x rays and radio waves from galactic and extragalactic objects strongly indicate the occurrence of plasma processes in those objects similar to those in the Earth's magnetosphere. The magnetosphere thus represents a uniquely accessible laboratory in which one can observe and understand the natural processes that lead to hot plasmas, energetic charged particles, UV emissions, and ENA's. Given the enormous influence of visual information on human insight and knowledge, the dissemination of the first images of the magnetosphere promises to change the prevailing views and interpretations of nature, from those based on local observations to those based on global, integrated, and interrelated concepts. Natural plasmas will be viewed thereafter as whole systems with boundaries, gradients, and connections to surrounding systems. In this way, it is expected that IMI will open a new window into the plasma universe.

3. To what extent is the mission or initiative expected to resolve them?

Despite the successes that in situ investigations of the magnetosphere have had in explaining local processes, in the magnetosphere most of the spatial and temporal relationships of these processes to each other and to global features of the magnetosphere remain to be established. Exactly when and where are plasmas first heated in a substorm? What processes occur simultaneously in the Northern and Southern Hemispheres? How does the shape of the magnetosphere change when the solar wind pressure increases or decreases? These are but a few of the basic questions to which unequivocal answers are necessary but currently unavailable, due to the lack of a global view of the magnetosphere obtained quickly enough to capture an "unblurred" view of these processes. In fact, no global view, blurred or not, now exists. Thus, key questions such as those above remain unresolved. IMI observations will



resolve many of these global issues and will provide a measured framework within which to place the local observations. The eventual combination of both global observations and local observations throughout this astrophysical system, the Earth's magnetosphere, will be a first-ever occurrence and should provide a quantum step forward in understanding planetary magnetospheres. The present technology shows that images with the requisite sensitivity and resolution to resolve these major issues can be built. Past experience shows that such new measurements engender insights and advances well beyond those foreseen at the time.

## **B. Generality of Interest**

### **1. Why is the mission or initiative important or critical to the proposing scientific discipline?**

In 1988, the Space Science Board of the National Academy of Sciences reported the results of a task group study, which identified imaging of the Earth's magnetosphere as a novel and exciting initiative for the 1995 to 2015 time period.<sup>2</sup>

To understand the magnetosphere and its dynamics requires the combination of both global observations and local observations throughout the system. Local observations, the primary measurement mode to date in magnetospheric physics, have been extremely valuable in delineating the local processes that operate in specific regions of the magnetosphere. The initial global observations of one magnetospheric region, the aurora, have been revolutionary in the perspective and knowledge of the aurora. However, there has been a nearly complete lack of global observations of the entire magnetosphere. Briefly, the need for global observations is twofold: (1) they put local processes into perspective, and (2) they show the summation of local effects.

However, words cannot fully express the need for and importance of global observations. Without them, our knowledge and understanding is deficient; restricted to extrapolation and/or guesswork. We remain as limited as the proverbial blind man examining an elephant; and in magnetospheric physics, from a global perspective, that is our position. Our observations have been local and separated, not only in space but also in time. Consequently, while we have developed a good, and in some cases a remarkable, understanding of how these processes and locales work together to form the whole; we have no accurate overall picture. To be sure, we have cartoons and schematic overviews that are valuable in organizing our results and in guiding future work. Also, we are beginning to see some very exciting results from computer simulations that present another valuable perspective of the magnetosphere and its dynamics. However, without actual global observations, cartoons and simulations represent our global horizons.

The need for global observations is not a new concept. For example, ground-based researchers have been aware of the importance of global observations for over a century and have continually emphasized the use of worldwide networks of observing stations to uncover the large-scale behavior of the systems being observed.

The fact that global observations also provide basic, quantitative information on parameters such as global current systems, global field configurations, and global conductivities underscores the expectation that when these images become available, significant fundamental advances in our understanding of planetary magnetospheres will result. We expect that the existence of global images will stimulate the creation of new concepts and new ways of thinking about the magnetosphere.

2. What impacts will the science accomplished by the mission or initiative have on other disciplines?

The IMI images will provide a new window to the plasma universe. The impact of this new global perspective will be felt in all space science disciplines in which plasma physics is important. For example, through the global images obtained, it is expected that the IMI will provide a totally new perspective, both quantitatively and qualitatively, on the global and macroscale features of the magnetosphere and how it maps into the ionosphere/thermosphere/mesosphere (ITM) regions. For example, such new results that concern global electrical conductivity, key elements of the global electric circuit, and global energy deposition into the upper atmosphere will directly influence work in the ITM disciplines.

Similarly, the expected new magnetospheric perspectives and understanding to be obtained from the use of both global observations and local observations will be directly applicable to considerations of the formation and evolution of large-scale magnetic/plasma features in the solar corona. Solar physics should thus reap many of the benefits expected from an IMI mission.

IMI results will be applicable to astrophysical plasma systems that typically emit nonthermal radiation, which is remotely observed (e.g., x rays, radio waves, and cosmic rays). The Earth's magnetosphere is one such nonthermally radiating system, and it has at least three highly desirable attributes for study. First, it is accessible to direct local probing of its plasma, fields, and energetic particle content. Secondly, the Earth's magnetosphere not only can be remotely observed, as with distant astrophysical systems, it can be remotely imaged. Thirdly, the Earth's magnetosphere consists of a rotating, magnetized object embedded in a high-speed stellar plasma outflow; a situation that gives rise to hot plasmas, energetic charged particles, energetic neutral atoms, radio waves, x rays, and FUV emissions. Much is known of the specific plasma processes that account for these emissions. It remains for IMI to provide the initial global perspective and, in combination with local observations, to present the beginning of a quantitative understanding of the overall system.

Finally, the IMI results will be applicable directly to other planetary magnetospheres. It is important to realize the synergism of comparing the Earth to other solar system objects. Earth-based images of the sodium nebulae of Mercury and Jupiter's magnetospheres have already been obtained. Magnetospheric imagery of Saturn is being considered for the *Cassini* mission. IMI observations will provide a key link in the development of systematic comparative planetology, especially in the formation and dynamics of planetary magnetospheres and their interactions with planetary atmospheres, rings, and satellites.

3. Is there a potential for closing a major gap in knowledge, either within an important discipline or in areas bridging disciplines?

The major gap in knowledge of the magnetosphere is that of its global shape and dynamics. In fact, knowledge of the global characteristics of even the plasmaspheric, ring current, and inner plasma sheet component regions of the magnetosphere are similarly severely limited. IMI will literally provide the "map" in which to place the discoveries of 30 years of local fields and particle observations. It can reasonably be expected that IMI will change dramatically both present perceptions and interpretations of magnetospheric features. An example of a key science problem that requires global imagery for its solution is that of the causes and effects of magnetospheric substorms. Substorms are apparently the principal regulator of magnetospheric energy flows, but how they begin and what happens thereafter is still the subject of widely divergent interpretations of local observations. Global images are needed to observe the behavior of the magnetosphere during substorms, to incorporate local observations into this global view, and together to resolve many of the existing basic issues in magnetospheric substorm studies.

### C. Potential for New Discoveries and Understanding

1. Does the mission or initiative provide powerful new techniques for probing nature? What advances can be expected beyond previous measurements with respect to accuracy, sensitivity, comprehensiveness, and spectral or dynamic range?

Global ENA imaging is a new technique that awaits a flight opportunity. The physical basis for both the instrument and the ENA emissions from magnetospheric features is well established. Using serendipitous flight data, pioneering studies have validated the concept. What is needed is the flight of specifically designed instrumentation to obtain ENA images of higher sensitivity and resolution than the pioneering observations. Improvements in sensitivity and spatial resolution of 100 fold, and extended energy and composition coverage are attainable with flyable instruments.

Plasmaspheric He<sup>+</sup> 304 imaging is also a new technique. Using a “line-of-sight” scanning instrument in low-Earth orbit, early flight observations have been made. This has established the required sensitivity for an instrument to obtain global images of the plasmasphere. The technology is well established. The application of this technology to plasmaspheric imaging is new.

Geocoronal Lyman- $\alpha$  and auroral FUV observations are techniques of proven value, principally from the Dynamics Explorer results. Their role on the IMI platform is for simultaneous global mapping and connection to past observations. They complete the spatial picture by establishing which auroral patterns correspond to which plasmaspheric and magnetospheric events, such as the ring current and inner plasma sheet.

High-resolution imaging of auroral x rays utilizes techniques developed to image the Sun and other astrophysical sources. IMI x-ray images of Earth obtained with a spatial resolution of 10 to 20 km, together with energy spectral information for these x rays, will be a considerable improvement over previous x-ray images, obtained by polar orbiting spacecraft. The IMI x-ray data, together with ENA images, will provide unique information on energetic particle sources.

2. Is there a potential for revealing previously unknown phenomena, processes, or interactions?

Previous experience shows that new phenomena, processes, interactions, and discoveries invariably result from the introduction of new observations. The new emphasis of the IMI is on the global magnetosphere. The initial results from IMI should be full of hitherto unobserved and unexpected features and events. Making a list of these would involve mostly speculation at this time because IMI is a “discovery” mission.

3. In what ways will the mission or initiative answer the fundamental questions or stimulate theoretical understanding of fundamental structures or processes related to the origins and evolution of the universe, the solar system, the planet Earth, or of life on Earth?

Being observed in the Sun, throughout the heliosphere, at other planets, at neutron stars, and in the global behavior of star systems and galaxies, magnetospheres and the processes occurring within them are present throughout the cosmos. In an exciting and unique manner, the IMI addresses fundamental questions of how real, large-scale, naturally occurring plasmas behave in one of these cosmic plasmas, the Earth’s magnetosphere. The results are expected to be applicable directly to several fundamental aspects of other members of the family of astrophysical plasmas. Much of the present knowledge of plasma behavior is based on idealized systems convenient for theoretical treatment, on laboratory experiments, or on highly localized observations of space plasmas. Inherently difficult but critical aspects of

global plasma behavior, such as complex geometries, boundaries, and nonlinearities, are often omitted. It is expected that IMI observations will provide observations that address these important questions and will pave the way for theoretical advances in this arena.

4. In what ways will the mission or initiative advance understanding of important and widely occurring natural processes and stimulate modeling and theoretical description of these processes?

Being observed at the Sun, throughout the heliosphere, at other planets, at neutron stars, and in the global behavior of star systems and galaxies, magnetospheres and the processes that occur within them are pervasive in the cosmos. Because of the ubiquitous presence of plasmas throughout the universe, the knowledge to be obtained from IMI about the global nature of the system of magnetized plasmas will have wide impact. Indeed, as stated earlier, IMI will provide a new window to the plasma universe. An even greater advance is expected from IMI, because the availability of its images will represent the first time that one will be able to incorporate both global and local observations of an astrophysical plasma, the Earth's magnetosphere, into an observed global perspective. This will provide one with a powerful observational data base to study astrophysical plasma systems.

The observations from IMI will provide the first observational test of presently available global magnetospheric models and simulations. We are confident that both the prospect and availability of global observations will greatly stimulate the modeling and simulation of these magnetized plasma systems.

5. Is there a potential for discovering new laws of science, new interpretations of laws, or new theories concerning fundamental processes?

It is not anticipated that the IMI will result in the discovery of new physical laws. However, new understandings of how present laws of physics operate in complex many-component natural systems can be expected. For example, the IMI will address directly the applications of the well-known physical laws of Maxwell's equations for the electromagnetic field and of the classical equations of motion which govern the motions of charged particles in those fields to an important system in nature, the Earth's magnetosphere. That the applications of these laws and the determination of predictive physical solutions is difficult is surmised easily from the very sparse set of theoretical statements that can be made about the behavior of the magnetosphere. Clearly, the goal is to be quantitative and predictive. It will require earnest pursuit of correct theoretical explanations of IMI observations to achieve this.

#### **D. Uniqueness**

1. What are the special reasons for proposing this investigation as a mission in space or as an Office of Space Science and Applications (OSSA) initiative? Are there other ways that the desired knowledge could be obtained?

The Earth's atmosphere is opaque to the emissions that need to be imaged, therefore, an orbiting platform is essential. Further, the perspective of the images benefits greatly from a high-altitude observation point, typically  $6-R_E$  geocentric distance.

2. Is there a special requirement for launching the mission or starting the initiative on a particular time schedule?

The IMI mission could be launched and operated at any time. It will benefit from simultaneous local fields and particles observations from other magnetospheric spacecraft. Magnetospheric responses

at all stages of the solar cycle need to be studied, hence, there is no requirement for specific launch timing. Orbital choices can be made that will optimize performance for any launch time.

## V. PROGRAMMATIC CONSIDERATIONS

### A. Feasibility and Readiness

#### 1. Is the mission or initiative technologically feasible?

The core measurement set can be made with existing or fully developed instruments. A spacecraft system that has the performance characteristics of the POLAR spacecraft, now being built for the ISTP mission, could perform the IMI mission. In fact, it would be possible and of great benefit to the IMI mission to conduct a pathfinding imager mission in the small-class (SMEX) or large-class (BEX) explorer program as soon as possible. Having an ENA imager, EUV imager, and FUV imager as core payload for such a mission can be accomplished quickly and relatively inexpensively.

#### 2. Are substantial new technological developments required for success?

Mission success is attainable within the presently available technologies for space flight.

#### 3. Are there adequate plans and facilities to receive, process, analyze, store, and distribute data at the expected rate of acquisition?

Preliminary estimates of the expected data rates are within the capabilities of modest downlinks. The ground system to process and distribute images is yet to be defined. Innovative techniques to distribute rapidly and directly significant portions of the images are under study. Early and wide distribution of the imaging data is a goal.

#### 4. Are there adequate plans and funding identified for scientific analysis of the data?

A plan for end-to-end acquisition and analysis of the images is under development. Funding for full scientific analysis will be included in the mission fiscal profiles. No exceptional demands on data analysis and interpretation have been identified yet that would make IMI analysis costs significantly higher than typical NASA missions.

#### 5. Is there an adequate management and administrative structure to develop and operate the mission or initiative and to stimulate optimum use of the results?

Marshall Space Flight Center (MSFC) management has offered the services of the Center during the study phase. Present indications are that MSFC resources would be available for subsequent phases, should OSSA strategy require it.

## **B. Space Operations and Infrastructure**

### **1. What are the long-term requirements for space operations, including launches, replacement and maintenance of instruments, and data acquisition and transfer?**

IMI is contemplated as a single launch followed by 2 years of orbital operation during the prime mission phase. Some orbit adjust capability appears to have scientific merit in optimizing the duration of most favorable observing. It is expected that IMI will prove to be of high value and that an extended mission will be an option which merits serious consideration.

### **2. What current and long-term infrastructure is required to support the mission or initiative and the associated data processing and analysis?**

Routine NASA mission operations support is needed. Since the targets for imaging are known, it is expected that on-orbit operation and scheduling of spacecraft actions will be highly repetitive and will not require the development of unique daily observing programs. Instrument technical constraints are expected to be met easily. Other aspects of the ground system to support IMI will be defined later. IMI will place no exceptional demands on ground information processing capability or science communications.

## **C. Community Commitment and Readiness**

### **1. Is there a community of outstanding scientists committed to the success of the mission or initiative?**

High interest in magnetospheric imaging missions has been evident in proposals submitted to the Delta-class explorer program as well as to the small-class explorer competition. Magnetospheric imaging has been recommended strongly by panels of the National Academy and by the Magnetospheric Physics Panel of the Space Physics Strategy Implementation Study. In a NASA-requested study published in 1988, the Space Studies Board recommended magnetospheric imaging as an initiative for the 1995 to 2000 time period. The Solar Terrestrial Science Strategy Workshop, sponsored by NASA MSFC in 1988, strongly recommended that "... steps be taken to advance capabilities to view solar-terrestrial phenomena as two-dimensional images in many different wavelength bands." The IMI concepts and plans directly follow a well-established track of scientific recommendations from the magnetospheric physics community.

### **2. In what ways will the community participate in the operation of the mission or initiative and in the analysis of the results?**

It is expected that investigation teams drawn from the cadres of experienced magnetospheric scientists and instrument specialists will form around the prime measurement objectives. These teams will produce the instrumentation and conduct the prime data analysis and interpretation. Guest investigators and multidisciplinary scientists can be selected to complete science coverage as needed. It is expected that experienced and expert scientists from the ionospheric, astrophysics, and solar physics communities will give serious consideration to participation in the IMI mission. Dissemination of reconnaissance images of the magnetosphere to an extended community of potential science users is planned. This should result in a wide variety of rapid and retrospective studies as well as specific campaigns.

## **D. Institutional Implications**

### **1. In what ways will be mission or initiative stimulate research and education?**

Images are easily accessible to a broad public. IMI pictures will stimulate curiosity and provide insights and familiarity with space plasmas that do not exist at this time.

IMI will provide synoptic data throughout the inner magnetosphere, and it will provide a catalyst for unifying space plasma theory, modeling, and data analysis, which have previously been based on single point measurements. Images are readily accessible to the general public and will serve to stimulate interest and insights in magnetospheric physics and help in the efforts to educate the public about this field.

### **2. What opportunities and challenges will be presented to NASA Centers, contractors, and universities?**

It is expected that university, field Center, contractor, and other scientists will assemble into investigation teams and propose to furnish the needed instrumentation for the IMI project. Data analysis, interpretation, and application of IMI results will extend beyond the IMI-specific project efforts and enhance other magnetospheric missions.

### **3. What will be the impact of the mission or initiative on O SSA activities? Will new elements be required? Can some current activities be curtailed if the mission or initiative is successful?**

Global imaging techniques are more efficient at characterizing global aspects of the state of the magnetosphere than multiple local platforms. The appropriate balance between local and global observations can be determined only after both have been simultaneously available for a reasonable time. This awaits the first use of quantitative imagery in magnetospheric physics, namely, IMI.

## **E. Collaborative Involvement by Other Agencies or Nations**

### **2. Does the mission or initiative provide attractive opportunities for involving leading scientists or scientific teams from other agencies or other countries?**

The IMI project has natural segmentation along the lines of the five core measurements. An international solicitation of investigations is entirely appropriate. While the spacecraft technology can be a modest adaptation of that for the U.S. *POLAR* spacecraft, a foreign spacecraft could be procured. Spacecraft systems technology appears to be within the capabilities of European and Japanese providers. As of this writing, however, the Working Group has not yet discussed any international collaborative possibilities.

### **2. Are there commitments for programmatic support from other nations, agencies, or international organizations?**

International collaborations on IMI have not yet been discussed.

## F. Costs of the Proposed Mission or Initiative

A prephase-A cost study has been performed by the Program Development Office at MSFC. The items costed included the spacecraft, instruments, integration and test, program support, fees, and contingency. Costs associated with prelaunch and postlaunch science support, operations, the launch system, and ground-system development are not included. Two cost estimates have been determined, based on use of the ISTP *POLAR* spacecraft (A) and on the new spacecraft design (B).

1. What are the total direct costs, by year, to the O SSA budget?

### O SSA Mission Costs\*

Design Model	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	Total
A	100k	200k	800k	2.6M	33M	73M	57M	14M	180.7M
B	100k	200k	800k	2.6M	48M	105M	83M	19M	258.7M

\*Note, as stated above, not all costs are included in the estimate.

2. What are the total costs, by year, to the NASA budget?

Total costs to the NASA budget beyond that shown above are not now available.

3. What portion of the total costs of the mission or initiative will be borne by other agencies or nations?

International cost sharing on IMI has not yet been discussed.

## VI. SOCIETAL AND OTHER IMPLICATIONS

### A. Contribution to Scientific Awareness or Improvement of the Human Condition

1. Are the goals of the mission or initiative related to broader public policy objectives such as human welfare, economic growth, or national security?

The ultimate, routine availability of global images of the magnetosphere will provide a major advance in the Nation's fledgling space weather service, operated by the National Oceanic and Atmospheric Administration. Such images will provide a definite increase in the accuracy of alerts and short-term predictability of magnetospheric plasma and charged-particle behavior that may have effects on a number of civilian and military ground-based and space-based operational systems.

2. What is the potential for stimulating technological developments that have application beyond this particular mission or initiative?

UV and ENA imaging technology will be driven by the process of optimizing the sensitivities and performance of the IMI instruments.



3. How will the mission initiative contribute to public understanding of the physical world and appreciation of the goals and accomplishments of science?

The pictures to be produced by IMI will address the most basic human sense, vision. The Earth's glowing plasma nebula, which has hitherto been hidden from view, will be rendered visible. It is expected that the images will excite curiosity as well as engender a public familiarity with magnetospheric concepts.

**B. Contribution to International Understanding**

1. Will the mission or initiative contribute to international collaboration and understanding?

It is anticipated that IMI would have international scientific investigators and co-investigators; at least, all would be eligible.

2. Do any aspects of the mission or initiative require special sensitivity to the concerns of other nations?

None have been identified by the Working Group.

**C. Contributions to National Pride and Prestige**

1. How will the mission or initiative contribute to national pride in U.S. accomplishments and to the image of the U.S. as a scientific and technological leader?

The IMI pictures will be a breakthrough of great public interest. It is expected that time-lapse "movies" of the Earth's magnetosphere, as it responds to solar and interplanetary disturbances, will be obtained.

2. Will the mission or initiative create public pride because of the magnitude of the challenge, the excitement or the endeavor, or the nature of the expected results?

Public pride has been great in past missions that produced images. IMI will be likewise a source of pride.

## REFERENCES

1. Colgate, S. (Chair): "Space Plasma Physics: The Study of Solar System Plasmas," volume 1, Reports of the Study Committee and Advocacy Panels, National Academy of Sciences, Washington, DC, 1978.
2. Scarf, F.L. (Editor): "Space Science in the Twenty-First Century—Imperative for the Decades 1995 to 2015," volume 1, Solar and Space Physics., National Academy Press, Washington, DC, 1988.



REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, Va 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Reference Publication	
4. TITLE AND SUBTITLE  Magnetosphere Imager Science Definition Team Executive Summary			5. FUNDING NUMBERS	
6. AUTHOR(S)  T.P. Armstrong,* D.L. Gallagher, and C.L. Johnson				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812			8. PERFORMING ORGANIZATION REPORT NUMBERS  M-795	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)  National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER  NASA RP-1379	
11. SUPPLEMENTARY NOTES  Prepared by Advanced Systems and Technology Office, Program Development. *University of Kansas.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT  Unclassified-Unlimited Subject Category 46			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  For three decades, magnetospheric field and plasma measurements have been made by diverse instruments flown on spacecraft in many different orbits, widely separated in space and time, and under various solar and magnetospheric conditions. Scientists have used this information to piece together an intricate, yet incomplete view of the magnetosphere. A simultaneous global view, using various light wavelengths and energetic neutral atoms, could reveal exciting new data and help explain complex magnetospheric processes, thus providing a clear picture of this region of space. This report summarizes the scientific rationale for such a magnetospheric imaging mission and outlines a mission concept for its implementation.				
14. SUBJECT TERMS  magnetosphere, geocorona, plasma sheet			15. NUMBER OF PAGES 36	
			16. PRICE CODE A06	
17. SECURITY CLASSIFICATION  Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT  Unlimited	





3 1176 01423 8811

National Aeronautics and  
Space Administration  
Code JTT  
Washington, DC  
20546-0001

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